## TITLE OF THE INVENTION

# MACHINE TO MANUFACTURE A FIBROUS MATERIAL WEB


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## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** The present application claims priority under 35 U.S.C. §119 of German Patent Application No. 100 61 274.1, filed on December 8, 2000, the disclosure of which is expressly incorporated by reference herein in its entirety.

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

**[0002]** The present invention relates to a machine to manufacture a fibrous material web, particularly a paper or cardboard web.

### 2. Discussion of Background Information

**[0003]** Particularly in the case of high-speed paper machines, a laminar air boundary layer can form on the paper web and the belts, such as screens, felts or the like, that support the web at least in segments. With increasing speed, this layer causes problems with respect to web travel. Included in these problems, among others, are excess pressure arising in a respective closing gap, web flutter, floating of the web or belt on rolls, cylinders or the like, etc. These problems occur in particular when the web or the affected belt feeds into a closing gap and the air that is carried along must be displaced from the gap. In doing so, the air must be carried away laterally and/or against the web travel direction.

**[0004]** However, it is difficult to displace the thin laminar air boundary layer from the gap, something which can be attributed particularly to its high speed, which can reach values in the order of magnitude of the web/belt speed, and its uniform alignment directly into the closing gap, which, in terms of alignment, represents the least favorable case.

**[0005]** Until now the following measures were used to attempt to reduce the cited disturbances that occur with respect to the web travel:

Favorable constructional arrangement of the various components of the paper machine in order to facilitate the outflow of excess air.

Ventilation devices such as suction and blower boxes to eliminate the excess air (suctioning off, air curtain as a wiper) and/or to stabilize the web run.

Guiding plates for the targeted removal of the excess air except for the remaining gap between the guiding plate and web or belt.

**[0006]** Using these types of measures, the laminar air boundary layer can be reduced partially at best and furthermore only with a considerable expenditure of energy.

## SUMMARY OF THE INVENTION

**[0007]** As a result, it is a goal of the invention to create an improved machine of the type mentioned at the outset in which the cited problems are eliminated.

**[0008]** In accordance with a first aspect of the invention, a machine to manufacture a fibrous material web, particularly a paper or cardboard web, is provided with at least one electrostatic air boundary layer swirler made up of a charging electrode as well as a counterelectrode to remove, at least partially, a laminar air boundary layer formed on the moved fibrous material web or a moved surface such as particularly a revolving belt, a rotating roll or the like, which is arranged in the machine direction of the fibrous material web or the moved surface in front of a gap in order to remove, at least partially, the laminar air boundary layer before it reaches the gap.

**[0009]** An electrostatic air boundary layer swirler should be understood as a device made up of a charging electrode as well as a counterelectrode, which generates a plasma current (electron and ion beam), which is fired at the fibrous material web or

the affected moved surface by electrostatic attraction. The laminar air boundary layer is disturbed by the plasma current generated between the charging electrode and the counterelectrode in such a way that it turns into a turbulent flow. The counterelectrode can be formed by a roll, a cylinder or a separate electrode, for example. In this connection, this counterelectrode can be grounded, in particular. The moisture content of the fibrous material web does not play a role in the breakup of the laminar air boundary layer that is supported by a corresponding electrical field, since the counterelectrode does not have to be formed by the charged fibrous material web, but can be, in particular, a grounded, electrically conductive counterelectrode, for example, a metal roll. This disintegration of a respective laminar air boundary layer supported by an electrical field should be differentiated from known electrostatic methods in which an (application) medium is attracted due to the potential difference between the medium and an electrically charged fibrous material web.

**[0010]** Among other things, the invention takes advantage of the circumstance that the turbulent flow portion generated by way of the electrostatic air boundary layer swirler can be displaced more easily due to its chaotic structure, something which can be attributed particularly to the fact that from now on nonuniform or different flow directions are produced and smaller speed components occur in the direction of the closing gap. In addition, the previously mentioned measures with respect to the most favorable possible constructional arrangement as well as the ventilation devices cited can now be used optimally particularly also with the disintegration of the laminar air boundary layers since they mainly influence the turbulent flow.

**[0011]** Due to the solution in accordance with the invention, an improvement in the web run is achieved overall due to the elimination or reduction of interfering air currents. The elimination or reduction of interfering air currents is facilitated by the partial or complete conversion of the laminar air boundary layer formed on the fibrous

material web or the relevant belt (e.g., screen, felt or the like) into a turbulent current. One obtains, for example, a reduction in the air, which, for example, is dragged from a screen past an allocated seal (for example, felt seal, dynaseal or air meter) into the gap between a stabilizer and a drying screen, for example, thereby making a better web run possible in particular or achieving a reduction in the ventilator performance. The electrostatic air boundary layer swirler can be installed on the paper side or the back side of the screen, for example.

**[0012]** In all cases, the invention takes advantage in particular of the circumstance that the turbulent flow generated by the electrostatic air boundary layer swirler has a distinctly reduced tendency to be swept along into the gap.

**[0013]** By the way, the electrostatic air boundary layer swirler can be designed in particular as described in WO 97/03009, which is expressly incorporated by reference in its entirety, for example. Although an electrostatic air boundary layer swirler is thus already known from this WO 97/03009, this known electrostatic air boundary layer swirler is provided in combination with a dryer. Thus, with different dryer types, such as IR dryers and warm-air dryers, for example, the laminar air boundary layer reduces efficiency, since the heat transport and material transport are partially shielded by the stable laminar air boundary layer. A turbulent flow shows evidence of this resistance only to a much lower degree.

**[0014]** In a preferred embodiment of the machine in accordance with the invention, the distance between the electrostatic air boundary layer converter and the gap is a maximum of approximately 1000 mm, with it lying preferably in a range of approximately 100 mm to approximately 500 mm.

**[0015]** Alternatively or additionally, it is advantageous if a deflecting strip is provided in the machine direction between the electrostatic air boundary layer swirler and the gap in order to deflect at least a portion of the swirled air from the fibrous

material web or the moved surface. While with the use of only a guiding plate or the like, the laminar air boundary layer is not influenced, as a rule, since its thickness in general is distinctly less than the technically realizable gap between this type of guiding plate and the fibrous material web or the moved surface, only a portion at least of the laminar air boundary layer is also carried away with the deflecting strip arranged behind an electrostatic air boundary layer swirler, since at least a portion of the swirled air is deflected with this deflecting strip. The swirled air has a greater density than the laminar air boundary layer. As a result, the air quantity that flows through the remaining residual gap between the fibrous material web or the relevant moved surface and the deflecting strip, is thereby further reduced.

**[0016]** Alternatively or additionally, it is advisable if a deflecting strip is provided in the machine direction in front of the electrostatic air boundary layer swirler, in order to deflect at least a portion of the swept along air from the fibrous material web or the moved surface. In this case as well, the circumstance is utilized that a turbulent flow has a lower tendency to be swept along into the gap and flows off better into the area provided for this purpose.

**[0017]** The electrostatic air boundary layer swirler and/or the relevant deflecting strips are practically arranged again in front of the gap at a maximum distance of approximately 1000 mm, with this distance again preferably lying in a range of approximately 100 mm to approximately 500 mm.

**[0018]** Basically, it is also possible to arrange a deflecting strip both in front of as well as behind the electrostatic air boundary layer swirler.

**[0019]** Alternatively or additionally, it is advantageous if a suction device is provided between the electrostatic air boundary layer swirler and the gap in order to draw off at least a portion of the swirled air from the fibrous material web or the moved surface.

**[0020]** While a laminar air boundary layer can be reduced only negligibly via suctioning with a high expenditure of energy, a turbulent flow can be influenced comparatively well. The electrostatic air boundary layer swirler breaking up the laminar air boundary layer at least partially into a turbulent flow can, for example, be arranged again in front of the gap at a maximum distance of approximately 1000 mm, whereby this distance can again lie particularly in a range of approximately 100 mm to approximately 500 mm. In connection with this, the excess swirled air is removed with the suction device arranged to the fibrous material web or the relevant moved surface, whereby the desired air pressure in front of the closing gap can be regulated accordingly.

**[0021]** The suction device is advantageously divided into sections at right angles to the machine direction of the fibrous material web or the relevant moved surface and can be controlled and/or adjusted section by section. As a result, suctioning that can be controlled zone by zone is possible in order to be able to remove locally different volumes.

**[0022]** The electrostatic air boundary layer swirler can in particular also be provided in combination with at least one deflecting strip as well as with one suction device.

**[0023]** A corresponding use of electrostatic air boundary layer swirlers is conceivable, for example, in the press section, the drying section and/or in the area of a machine calender or a calender.

**[0024]** The relevant gap can be formed, for example, between the fibrous material web or the moved surface and a roll or a cylinder, between a moved surface releasing the fibrous material web and a moved surface accepting the fibrous material web, whereby an electrostatic air boundary layer swirler can be assigned to at least one of these two moved surfaces, or between a belt releasing the fibrous material web and

a belt accepting the fibrous material web. The gap can also be formed, for example, between a smooth moved surface releasing the fibrous material web, preferably a smooth roll, and a moved surface accepting the fibrous material web. In the latter case, the moved surface accepting the web can be formed by a revolving belt or a roll, for example.

**[0025]** In the case of an functional, practical embodiment, at least one moved surface is formed by a screen belt, a felt belt or the like.

**[0026]** In certain cases, it is advantageous if at least one electrostatic air boundary layer swirler arranged in the area of a web transfer location is provided. In this connection, the fibrous material web can be accepted in the area of the transfer location by a felt, for example.

**[0027]** In certain cases, it is advantageous if at least one electrostatic air boundary layer swirler arranged behind a double felt press is provided.

**[0028]** In certain cases, it can also be advantageous if at least one electrostatic air boundary layer swirler is provided, which is arranged in the area of a web transfer location with a web releasing and/or a web accepting smooth roll.

**[0029]** It is basically possible, for example, to arrange at least one electrostatic air boundary layer swirler in front of a single felted press.

**[0030]** In the case of an appropriate practical embodiment of the machine in accordance with the invention, at least one electrostatic air boundary layer swirler is provided in combination with a seal assigned in particular to a stabilizer or the like. In this connection, for example, at least one electrostatic air boundary layer swirler can be provided in combination with a seal on a stabilizer in a single-tier drying section in particular. The seal can be filled by a felt seal, a floating seal blade, an air knife and/or the like, for example.

**[0031]** Nozzle moisteners are used in paper machines for remoistening (initial or surface) and moisture profiling of fibrous webs with water. The efficiency of moistening decreases with increasing web speeds and decreasing spray drop size. Two-component nozzles with drop diameters of approximately 20 $\mu$m to approximately 80 $\mu$m are used in modern nozzle moisteners. In the case of web speeds above approximately 1000 m/min., the efficiency is only approximately 40% to approximately 60%. The remaining quantity of spray water is swept along with the ambient air.

**[0032]** Moreover, steam moisteners are used to influence quality (gloss, smoothness) in machine calenders, particularly supercalenders.

**[0033]** Furthermore, steam blower boxes are used in paper machines in the press section to increase the temperature of the fibrous material web. With increasing temperature, the viscosity of the water in the still very moist web drops, making it easier to press it out in the subsequent press nip. A portion of the steam does not reach the web due to the laminar air boundary layer.

**[0034]** As a result, another goal of the invention is increasing the efficiency, uniformity and application quality of the nozzle moisteners for remoistening and moisture profiling of a fibrous material web during the manufacturing process. In addition, an increase in the efficiency and particularly the uniformity and the application quality is to be achieved by nozzle moisteners in so-called "moisture gradient calendering." A further goal of the invention is increasing the efficiency, uniformity and application quality of steam moisteners in machine calenders. Moreover, an increase in the efficiency and uniformity of steam blower boxes in the press section is to be achieved.

**[0035]** According to another aspect of the invention, a machine to manufacture a fibrous material web, particularly a paper or cardboard web, is provided with at least

one electrostatic air boundary layer swirler made up of a charging electrode as well as a counterelectrode to remove, at least partially, a laminar air boundary layer formed on the moved fibrous material web, which is provided in combination with a nozzle moistener impinging the fibrous material web in order to remove, at least partially, the laminar air boundary layer in the web travel direction before the fibrous material web is moistened by the nozzle moistener.

**[0036]** Such a combined use of a nozzle moistener with an electrostatic air boundary layer swirler is conceivable on fibrous material webs with all dry matter contents and with dry matter contents less than approximately 95%, in particular.

**[0037]** In the case of steam moisteners, material transport is normally disturbed by the laminar air boundary layer. The disintegration of the laminar air boundary layer by the use of an electrostatic air boundary layer swirler in accordance with the invention increases the efficiency of the moistening to presumably more than approximately 70%. Furthermore, the drops are subject to kinematic interferences (such as deflection of the of the spray direction) to a lesser degree, which produces better uniformity of application. With lower kinematic interferences, the danger of colliding with neighboring drops is also reduced so that undesirably large drops are avoided and application quality is improved.

**[0038]** The electrostatic air boundary layer swirler is practically arranged in the web travel direction directly in front of the nozzle moistener. In this connection, the distance between the electrostatic air boundary layer swirler and the nozzle moistener can be less than or equal to approximately 1.5 m, in particular.

**[0039]** The nozzle moistener can be provided in particular with single-component nozzles/hydraulic atomizer nozzles and/or two-component nozzles/pneumatic atomizer nozzles.

**[0040]** The use in particular of a nozzle moistener designed as an application nozzle moistener is also possible.

**[0041]** A preferably flexible deflecting strip can be optionally attached between the electrostatic air boundary layer swirler and the nozzle moistener. This strip carries off the swirled air up to the remaining smallest possible gap between the web or the relevant moved surface and the strip. This remaining gap can lie in a range of approximately 0.5 cm to approximately 2.0 cm, for example. Interference with the atomizing cone of the nozzles by the air quantity carried along by the web is clearly reduced by this type of strip. The nozzles spray in a surrounding field that is largely free of cross-currents. The combination of the air boundary layer swirler and deflecting strip is clearly more effective than a deflecting strip alone, since the turbulent air layer has a greater thickness, i.e., expansion in the z-direction than the laminar air boundary layer. Optionally, a suctioning of the swirled laminar air boundary layer can also be provided.

**[0042]** Nozzle moisteners or nozzle dampeners can be used to apply all sprayable media during paper manufacturing and finishing. The currently usable applications are remoistening and moisture profiling, for example. The dry matter content of the fibrous material web in this case is between approximately 50% and approximately 98%. A further application is so-called "moisture gradient calendering" whereby a thin, uniform and film-like water layer is sprayed on the surface of the web in order to achieve similar improvements in quality as with steam moisteners. Until now, this method has still failed because of inadequate spray quality since, at high web speeds, the required drop size of approximately 20 $\mu$m for a film-like spray application does not uniformly reach the web due to the interfering laminar air boundary layer and other air currents. This type of method can now be applied due to the use of an electrostatic air boundary layer swirler in accordance with the invention.

**[0043]** In the case of these applications, water in particular, is planned as the spray medium, which can be heated as a option or mixed with additives such as tensides to reduce the surface tension and viscosity. Alternatively, binding agents, preferably starch, can also be used as a spray medium. These types of application nozzle moisteners are used to improve the paper properties, such as printability, or to increase the strength/surface strength of the paper. Alternatively, dyes can also be used as a spray medium.

**[0044]** In accordance with a further aspect of the invention, a machine to manufacture a fibrous material web, particularly a paper or cardboard web, is provided with at least one electrostatic air boundary layer swirler made up of a charging electrode as well as a counterelectrode to remove, at least partially, a laminar air boundary layer formed on the moved fibrous material web, which is provided in combination with a steam moistener impinging the fibrous material web in order to remove, at least partially, the laminar air boundary layer in the web travel direction before the fibrous material web is moistened by the steam moistener.

**[0045]** Conventional steam moisteners in particular can be used as steam moisteners. In this connection, the use of commercially available so-called "gloss profilers" and "smoothness profilers," for instance, is conceivable.

**[0046]** In the case of steam moisteners, the laminar boundary layer normally interferes with material transport. This disadvantage is eliminated by the invention.

**[0047]** The electrostatic air boundary layer swirler is arranged in the web travel direction preferably directly in front of the steam moistener. In doing so, the distance between the electrostatic air boundary layer swirler and the steam moistener is appropriately less than or equal to 1.5 m.

**[0048]** A suctioning for the swirled laminar air boundary layer is possible as an option.

**[0049]** In accordance with another aspect of the invention, a machine to manufacture a fibrous material web, particularly a paper or cardboard web, is provided with at least one electrostatic air boundary layer swirler consisting of a charging electrode as well as a counterelectrode to remove, at least partially, a laminar air boundary layer formed on the moved fibrous material web, which is provided in combination with a steam blower box impinging the fibrous material web in order to remove, at least partially, the laminar air boundary layer in the web travel direction before the fibrous material web is bombarded with steam by the steam blower box.

**[0050]** In this connection, conventional steam blower boxes in particular can be used. Thus, the use of commercially available so-called "module steam" modules from Voith, for instance, is conceivable.

**[0051]** The laminar boundary layer normally interferes with material transport in the case of steam blower boxes, too. This disadvantage is again eliminated in accordance with the invention.

**[0052]** The electrostatic air boundary layer swirler is arranged in the web travel direction preferably directly in front of the steam blower box. In doing so, the distance between the electrostatic air boundary layer swirler and the steam blower box is appropriately less than or equal to approximately 1.5 m.

**[0053]** A suctioning for the swirled laminar air boundary layer is again possible as an option.

**[0054]** As a rule, i.e., with all design variations in accordance with the various aspects of the invention, a deflecting strip can be provided in the web direction of travel behind and/or in front of the electrostatic air boundary layer swirler in order to deflect at least a portion of the swirled or swept along air from the fibrous material web. In doing so, a gap in the range of approximately 0.5 to approximately 2.0 cm

is left between the fibrous material web or the relevant moved surface and a respective deflecting strip.

**[0055]** Alternatively or additionally, a suction device can be provided in the web direction of travel behind the electrostatic air boundary layer swirler in order to suction off at least a portion of the swirled air from the fibrous material web. In this connection, such a suction device can be provided in the web direction of travel in particular between the electrostatic air boundary layer swirler and a relevant deflecting strip.

**[0056]** If at least one electrostatic air boundary layer swirler is provided in combination with a nozzle moistener, it can be integrated into the nozzle moistener.

**[0057]** If at least one electrostatic air boundary layer swirler is provided in combination with a steam moistener, it can be integrated into the steam moistener.

**[0058]** If at least one electrostatic air boundary layer swirler is provided in combination with a steam blower box, it can be integrated accordingly into the steam blower box.

**[0059]** In another advantageous embodiment of the machine in accordance with the invention, a respective deflecting strip being used to deflect swirled air can be integrated into the relevant electrostatic air boundary layer swirler. In just the same way, nozzle moisteners with at least one integrated deflecting strip being used to deflect at least a portion of the swirled air are conceivable. Correspondingly, a respective deflecting strip being used to deflect swirled air, for example, can also be integrated into a steam moistener or a steam blower box.

**[0060]** A respective suction device being used to suction off at least a portion of the swirled air can also be integrated, for example, into the affected electrostatic air boundary layer swirler, nozzle moistener, steam moistener, steam blower box and/or the like.

**[0061]** In another advantageous embodiment of the machine in accordance with the invention, the electrostatic air boundary layer swirler is provided in combination with, for example, a moistener or a steam blower box as a unit separate from the moistener or the steam blower box.

**[0062]** The deflecting strip, provided in the web travel direction behind the electrostatic air boundary layer swirler and being used to deflect at least a portion of the swirled air, is preferably arranged in front of the area where the fibrous material web is bombarded by a moistener or steam blower box. The nozzle streams are thereby shielded from interfering air currents, for example.

**[0063]** If the electrostatic air boundary layer swirler is provided in combination with a moistener or a steam blower box in particular, a respective deflecting strip being used to deflect at least a portion of the swirled air can be integrated into the moistener or steam blower box.

**[0064]** However, in principle the use of a deflecting strip that is separate from the moistener and the steam blower box is also possible.

**[0065]** A sealing strip or the like is provided in the area of the rear end of the moistener or the steam blower box in order to prevent the exit of moisture and/or steam.

**[0066]** In another advantageous embodiment of the machine in accordance with the invention, the moistener or the steam blower box is provided with an exhaust in order to suction off excess air, steam and/or mist. Among other things, this type of exhaust is advantageous if strips are provided in front of and behind the web area bombarded by the moistener or steam blower box and/or two-component nozzles are being used.

**[0067]** Alternatively or additionally, a suction device can naturally also be provided in order to suction off at least a portion of the swirled air.

**[0068]** Additional advantageous embodiments of the machine in accordance with the invention are disclosed herein. In this connection, not just any combinations of the embodiments concerning the various aspects of the invention are conceivable, but beyond this also any combinations of the various embodiments of the different solution variations. In this connection, embodiments of solution variations concerning different aspects of the invention can also be combined with one another in any manner.

**[0069]** Furthermore, the invention relates to the use of an electrostatic air boundary layer swirler in combination with a nozzle moistener impinging a fibrous material web. This type of use is possible in particular in a machine of the type disclosed in the claims.

**[0070]** In addition, the invention relates to the use of an electrostatic air boundary layer swirler in combination with a steam moistener impinging a fibrous material web. This type of use is also possible in particular in a machine of the type disclosed in the claims.

**[0071]** Moreover, the invention relates to the use of an electrostatic air boundary layer swirler in combination with a steam blower box impinging a fibrous material web, whereby this type of use is also possible in particular in a machine of the type disclosed in the claims.

**[0072]** Furthermore, the invention relates to the use of an electrostatic air boundary layer swirler in combination with a deflecting strip arranged behind it and/or one arranged in front of it at a fibrous material web to deflect in particular a portion of the swirled air. This use is also possible in particular again in a machine of the type disclosed in the claims.

**[0073]** In addition, the invention relates to the use of an electrostatic air boundary layer swirler in combination with a suction device to suction off at least a portion of

the swirled air. This type of use of an electrostatic air boundary layer swirler is also possible in particular again in a machine of the type disclosed in the claims.

**[0074]** Beyond this, any combinations of the previously mentioned types of use are conceivable. Thus, the invention also relates in particular to the use of one or more electrostatic air boundary layer swirlers in combination with a moistener impinging a fibrous material web, particularly nozzle or steam moisteners, in combination with a steam blower box impinging a fibrous material web, in combination with a deflecting strip arranged behind it and/or one arranged in front of it at the fibrous material web and/or in combination with a suction device to suction off at least a portion of the swirled air. This type of use is also possible in particular again in a machine of the type disclosed in the claims.

**[0075]** Furthermore, the invention also relates to the use of an electrostatic air boundary layer swirler in combination with a moistener impinging a fibrous material web in the case of moisture gradient calendering. This type of use is also possible in particular again in a machine of the type disclosed in the claims. Moisture gradient calendering as such is described in more detail in the offprint "PRACTICAL ASPECTS CONCERNING MOISTURE GRADIENT CALENDERING" by A. Heikkinen et. al. in the *Wochenblatt für Papierfabrikation* (*Paper Fabrication Weekly*), Volume 127, 1999, No. 10, pp. 680 to 685, which is expressly incorporated by reference in its entirety. Finally, this type of use can take place again in combination with the previously mentioned types of use.

**[0076]** The invention also provides for a machine for use in manufacturing a fibrous material web comprising at least one electrostatic air boundary layer swirler arranged near a moving surface. The moving surface comprises at least one of the fibrous material web, a belt, a roll, a felt, and a surface which supports the fibrous material web. The at least one electrostatic air boundary layer swirler comprises at

least one charging electrode and at least one counterelectrode. The at least one electrostatic air boundary layer swirler is adapted to at least one of at least partially remove a laminar air boundary layer formed on the moving surface, and at least partially disturb a laminar air boundary layer formed on the moving surface.

**[0077]** The fibrous material web may be one of a paper and a cardboard web. The moving surface may comprise at least one of a revolving belt and a rotating roll. The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, whereby the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap. The at least one electrostatic air boundary layer swirler may be located a distance "a" from the gap. The distance "a" may be a maximum of approximately 1000 mm. The distance "a" may be in a range of approximately 100 mm to approximately 500 mm.

**[0078]** The machine may further comprise at least one deflecting strip arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The at least one deflecting strip may be arranged between the electrostatic air boundary layer swirler and the gap, whereby at least a portion of swirled air is deflected from the moving surface. The machine may further comprise at least one suction device arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The at least one suction device may be arranged between the electrostatic air boundary layer swirler and the gap, whereby at least a portion of swirled air is deflected from the moving surface. The at least one suction device may be adapted to suction the moving surface in zones. The at least one electrostatic air boundary layer swirler may

be located in a press section. The at least one electrostatic air boundary layer swirler may be located in a dryer section.

**[0079]** The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, wherein the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap, and wherein the gap is formed between the moving surface and one of a roll and a cylinder.

**[0080]** The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, wherein the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap, and wherein the gap is located downstream from a position where the fibrous material web separates from the moving surface.

**[0081]** The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, wherein the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap, and wherein the gap is formed between the moving surface and additional moving surface. The additional moving surface may comprise a belt.

**[0082]** The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, wherein the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap, and wherein the gap is formed between the moving surface and additional moving surface, whereby the moving surface comprises a smooth moving surface. The smooth moving surface may comprise a smooth roll.

**[0083]** The moving surface may comprise one of a revolving belt and a roll. The moving surface may comprise one of a screen belt and a felt belt. The at least one electrostatic air boundary layer swirler may be positioned in an area wherein the fibrous material web is transferred. The at least one electrostatic air boundary layer swirler may be positioned in an area wherein the fibrous material web is transferred to another moving surface. The other moving surface may be a felt. The other moving surface may be a smooth surface.

**[0084]** The at least one electrostatic air boundary layer swirler may be positioned near a single-felted press. The at least one electrostatic air boundary layer swirler may be positioned near a double-felted press. The machine may further comprise at least one of a seal and a stabilizer associated with the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler may be located in a single-tier drying section. The seal may comprise at least one of a felt seal, a floating seal blade, and an air knife.

**[0085]** The invention also provides for a machine for use in manufacturing a fibrous material web comprising at least one electrostatic air boundary layer swirler arranged near a moving surface. The moving surface comprises at least one of the fibrous material web, a belt, a roll, a felt, and a surface which supports the fibrous material web. The at least one electrostatic air boundary layer swirler comprises at least one charging electrode and at least one counterelectrode. At least one nozzle moistener is arranged near the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler is adapted to at least one of at least partially remove a laminar air boundary layer formed on the moving surface, and at least partially disturb a laminar air boundary layer formed on the moving surface.

**[0086]** The fibrous material web may be one of a paper and a cardboard web. The

at least one nozzle moistener may impinge the fibrous material web with a spray in order to remove, at least partially, the laminar air boundary layer. The spray may comprise moisture. The at least one electrostatic air boundary layer swirler may be arranged, with respect to a web travel direction, near to and in front of the at least one nozzle moistener. A distance between the at least one electrostatic air boundary layer swirler and the at least one nozzle moistener may be less than or equal to approximately 1.5 m. The at least one nozzle moistener may comprise at least one nozzle. The at least one nozzle may comprise at least two nozzles. The at least one nozzle moistener may comprise at least one of a single-component nozzle, a hydraulic atomizer nozzle, a two-component nozzle and a pneumatic atomizer nozzle. The at least one nozzle moistener may comprise an application nozzle moistener.

**[0087]** The machine may further comprise at least one deflecting strip arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The machine may further comprise a separating gap in the range of approximately 0.5 to approximately 2.0 cm being positioned between the moving surface and the at least one deflecting strip. The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, whereby the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap. The machine may further comprise at least one suction device arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The at least one suction device may be positioned between the at least one electrostatic air boundary layer swirler and a deflecting strip. The at least one electrostatic air boundary layer swirler may be integrated into the at least one nozzle moistener.

**[0088]** The invention also provides for a machine for use in manufacturing a fibrous material web comprising at least one electrostatic air boundary layer swirler arranged near a moving surface. The moving surface comprises at least one of the fibrous material web, a belt, a roll, a felt, and a surface which supports the fibrous material web. The at least one electrostatic air boundary layer swirler comprises at least one charging electrode and at least one counterelectrode. At least one steam moistener is arranged near the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler is adapted to at least one of at least partially remove a laminar air boundary layer formed on the moving surface, and at least partially disturb a laminar air boundary layer formed on the moving surface.

**[0089]** The fibrous material web may be one of a paper and a cardboard web. The at least one steam moistener may impinge the fibrous material web with a spray in order to remove, at least partially, the laminar air boundary layer. The at least one electrostatic air boundary layer swirler may be arranged, with respect to a web travel direction, near to and in front of the at least one steam moistener. A distance between the at least one electrostatic air boundary layer swirler and the at least one steam moistener may be less than or equal to approximately 1.5 m. The at least one steam moistener may comprise at least one nozzle.

**[0090]** The machine may further comprise at least one deflecting strip arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The machine may further comprise a separating gap in the range of approximately 0.5 to approximately 2.0 cm being positioned between the moving surface and the at least one deflecting strip. The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, whereby the at least one electrostatic air

boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap.

**[0091]** The machine may further comprise at least one suction device arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The at least one suction device may be positioned between the at least one electrostatic air boundary layer swirler and a deflecting strip. The at least one electrostatic air boundary layer swirler may be integrated into the at least one steam moistener.

**[0092]** The invention also provides for a machine for use in manufacturing a fibrous material web comprising at least one electrostatic air boundary layer swirler arranged near a moving surface. The moving surface comprises at least one of the fibrous material web, a belt, a roll, a felt, and a surface which supports the fibrous material web. The at least one electrostatic air boundary layer swirler comprises at least one charging electrode and at least one counterelectrode. At least one steam blow box is arranged near the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler is adapted to at least one of at least partially remove a laminar air boundary layer formed on the moving surface, and at least partially disturb a laminar air boundary layer formed on the moving surface.

**[0093]** The fibrous material web may be one of a paper and a cardboard web. The at least one steam blow box may impinge the fibrous material web with a steam in order to remove, at least partially, the laminar air boundary layer. The at least one electrostatic air boundary layer swirler may be arranged, with respect to a web travel direction, near to and in front of the at least one steam blow box. A distance between the at least one electrostatic air boundary layer swirler and the at least one steam blow box may be less than or equal to approximately 1.5 m. The machine may further comprise at least one deflecting strip arranged at least one of upstream of the at least

one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The machine may further comprise a separating gap in the range of approximately 0.5 to approximately 2.0 cm being positioned between the moving surface and the at least one deflecting strip.

**[0094]** The at least one electrostatic air boundary layer swirler may be positioned upstream of or in front of a gap, whereby the at least one electrostatic air boundary layer swirler removes, at least partially, the laminar air boundary layer formed on the moving surface before the laminar air boundary layer reaches the gap. The machine may further comprise at least one suction device arranged at least one of upstream of the at least one electrostatic air boundary layer swirler and downstream of the at least one electrostatic air boundary layer swirler. The at least one suction device may be positioned between the at least one electrostatic air boundary layer swirler and a deflecting strip. The at least one electrostatic air boundary layer swirler may be integrated into the at least one steam blow box.

**[0095]** The invention also provides for a machine for use in manufacturing a fibrous material web comprising at least one electrostatic air boundary layer swirler arranged near a moving surface. The moving surface comprises at least one of the fibrous material web, a belt, a roll, a felt, and a surface which supports the fibrous material web. The at least one electrostatic air boundary layer swirler comprises at least one charging electrode and at least one counterelectrode. At least one device for moistening is arranged near the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler is adapted to at least one of at least partially remove a laminar air boundary layer formed on the moving surface, and at least partially disturb a laminar air boundary layer formed on the moving surface.

**[0096]** The at least one electrostatic air boundary layer swirler may be one of located adjacent to and coupled to at least one deflecting strip. The at least one device for moistening may be one of located adjacent to and coupled to at least one deflecting strip. The at least one device for moistening may comprise at least one of a nozzle moistener, a steam moistener, a steam blow box, and a moisture spraying device. The at least one electrostatic air boundary layer swirler may be one of located adjacent to and coupled to at least one suction device. The at least one device for moistening may be one of located adjacent to and coupled to at least one suction device. The at least one electrostatic air boundary layer swirler may include at least one suction device. The at least one device for moistening may include at least one suction device. The at least one electrostatic air boundary layer swirler may include at least one deflecting strip. The at least one device for moistening may include at least one deflecting strip. The at least one electrostatic air boundary layer swirler may include the at least one device for moistening. The at least one device for moistening may include the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler may be coupled to the at least one device for moistening. The at least one device for moistening may be coupled to the at least one electrostatic air boundary layer swirler. The machine may further comprise a sealing strip arranged near the at least one device for moistening. The at least one device for moistening may be adapted to provide suctioning. The at least one device for moistening may be arranged in the area of a calender. The at least one electrostatic air boundary layer swirler may be arranged in the area of a calender.

**[0097]** The invention further provides for a method of manufacturing a fibrous material web using a device which comprises at least one electrostatic air boundary layer swirler arranged near a moving surface, the moving surface comprising at least one of the fibrous material web, a belt, a roll, a felt, and a surface which supports the

fibrous material web, the at least one electrostatic air boundary layer swirler comprising at least one charging electrode and at least one counterelectrode, at least one device for moistening arranged near the at least one electrostatic air boundary layer swirler, the method comprising subjecting the moving surface to a plasma current or a plasma stream, and at least partially removing a laminar air boundary layer formed on the moving surface.

**[0098]** The at least one electrostatic air boundary layer swirler may be one of located adjacent to and coupled to at least one deflecting strip. The at least one device for moistening may be one of located adjacent to and coupled to at least one deflecting strip. The at least one device for moistening may comprise at least one of a nozzle moistener, a steam moistener, a steam blow box, and a moisture spraying device. The at least one electrostatic air boundary layer swirler may be one of located adjacent to and coupled to at least one suction device. The at least one device for moistening may be one of located adjacent to and coupled to at least one suction device. The at least one electrostatic air boundary layer swirler may include at least one suction device. The at least one device for moistening may include at least one suction device. The at least one electrostatic air boundary layer swirler may include at least one deflecting strip. The at least one device for moistening may include at least one deflecting strip. The at least one electrostatic air boundary layer swirler may include the at least one device for moistening. The at least one device for moistening may include the at least one electrostatic air boundary layer swirler. The at least one electrostatic air boundary layer swirler may be coupled to the at least one device for moistening. The at least one device for moistening may be coupled to the at least one electrostatic air boundary layer swirler.

**[0099]** The method may further comprise a sealing strip arranged near the at least one device for moistening. The at least one device for moistening may be adapted to

provide suctioning. The at least one device for moistening may be arranged in the area of a calender. The at least one electrostatic air boundary layer swirler may be arranged in the area of a calender.

**[0100]** Other exemplary embodiments and advantages of the present invention may be ascertained by reviewing the present disclosure and the accompanying drawing.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0101]** The present invention is further described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments of the present invention, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

Fig. 1 shows a schematic representation of an electrostatic air boundary layer swirler arranged in front of a gap and used in a machine to manufacture a fibrous material web;

Fig. 2 shows a schematic representation of an arrangement comparable to that in Fig. 1 with a deflecting strip connected downstream from the electrostatic air boundary layer swirler;

Fig. 3 shows a schematic representation of an arrangement comparable to that in Fig. 1 with a deflecting strip connected upstream from the electrostatic air boundary layer swirler;

Fig. 4 shows a schematic representation of an arrangement comparable to that in Fig. 1 with a suction device connected downstream from the electrostatic air boundary layer swirler;

Fig. 5 shows a schematic representation of an electrostatic air boundary layer swirler used in the press section, which is arranged in the area of a web transfer location where the fibrous material web is accepted by a felt;

Fig. 6 shows a schematic representation of an electrostatic air boundary layer swirler used in the press section, which is arranged in the area of a web transfer location where the fibrous material web is accepted by a smooth roll;

Fig. 7 shows a schematic representation of two electrostatic air boundary layer swirlers used in the press section, of which one is arranged in the area of a transfer roll and the other is arranged in the area of a single-felted press;

Fig. 8 shows a schematic representation of an electrostatic air boundary layer swirler used in combination with a moistener in a machine to manufacture a fibrous material web; and

Fig. 9 shows a schematic representation of another exemplary embodiment of an arrangement with an electrostatic air boundary layer swirler used in combination with a moistener.

## DETAILED DESCRIPTION OF THE PRESENT INVENTION

**[0102]** The particulars shown herein are by way of example and for purposes of illustrative discussion of the embodiments of the present invention only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the present invention. In this regard, no attempt is made to show structural details of the present invention in more detail than is necessary for the fundamental understanding of the present invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the present invention may be embodied in practice.

**[0103]** The electrostatic air boundary layer swirlers 10 shown in Fig. 1 through 9 are each used in a machine to manufacture a fibrous material web 12, which can be in particular a paper or cardboard web.

**[0104]** The electrostatic air boundary layer swirlers 10 include a charging electrode 14 and particularly a grounded counterelectrode 16, which can be formed by a roll or the like.

**[0105]** A plasma current or plasma stream 18 (electron and ion beam) is generated by way of the electrostatic air boundary layer swirlers 10, which is fired at the fibrous material web 12 or the affected moved surface via electrostatic attractive power, thereby interfering with the laminar air boundary layer 20 (see Figs. 8 and 9, for example) in such a way that it turns into a turbulent air flow 22. The plasma current or stream 18 is generated between the respective charging electrode 14 and the associated counterelectrode 16, which can be formed by a roll or a corresponding counter element, for example.

**[0106]** As can be seen on the basis of Figs. 1 through 7, in particular, the respective electrostatic air boundary layer swirler 10 can be arranged, for example, in the machine direction L of the fibrous material web 12 or the relevant moved surface in front of a gap 24 in order to remove, at least partially, the laminar air boundary layer before it reaches the gap 24.

**[0107]** In the case of the moved surface, it can be in particular a revolving belt 26 or a rotating roll 28 (see Fig. 7).

**[0108]** Fig. 1 shows a schematic representation of an electrostatic air boundary layer swirler 10 arranged in front of a gap 24 and used in a machine to manufacture a fibrous material web 12, whose counterelectrode 16, for example, is formed by a grounded roll in particular. In this connection, the counterelectrode 16 can be in contact with the fibrous material web 12 or not.

**[0109]** In the case at hand, the gap 24 is formed between the fibrous material web 12 or a revolving belt 26 and roll 30 onto which the fibrous material web 12 or the revolving belt 26 winds in machine direction L. The turbulent current generated by the electrostatic air boundary layer swirler 10 has a lower tendency to be swept along into the gap 24 and flows off better into the areas provided for this.

**[0110]** The distance "a" between the electrostatic air boundary layer swirler 10 and the gap 24 is advantageously a maximum of approximately 1000 mm and preferably lies in a range of approximately 100 mm to approximately 500 mm.

**[0111]** Fig. 2 shows a schematic representation of an arrangement comparable to that in Fig. 1, in which, however, a deflecting strip 32 is connected downstream from the electrostatic air boundary layer swirler 10 in order to deflect at least a portion of the swirled air from the fibrous material web 12 or the revolving belt 26. In this connection, the deflecting strip 32 can be formed by a guiding plate or the like, for example. The swirled air has a greater density than the affected laminar air boundary layer. Correspondingly, the air quantity that flows through the remaining residual gap between the fibrous material web 12 or the revolving belt 26 and the deflecting strip 32 continues to decrease.

**[0112]** Fig. 3 shows a schematic representation of another arrangement comparable to that in Fig. 1, in which, however, a deflecting strip 32 is connected upstream from the electrostatic air boundary layer swirler 10. The distance "b" between the deflecting strip 32 and the gap 24 is advantageously a maximum of approximately 1000 mm and preferably lies in a range of approximately 100 mm to approximately 500 mm. The air being swept along is deflected by the deflecting strip 32 except for the remaining gap 34 between the deflecting strip 32 and the fibrous material web 12. The subsequent electrostatic air boundary layer swirler 10 breaks up the remaining laminar air boundary layer, at least partially, into a turbulent flow. The turbulent flow

has a lower tendency to be swept along into the gap 24 and flows off better into the areas provided for this.

**[0113]** A combination of the embodiments shown in Figs. 2 and 3 is also possible, for example, in which at least one deflecting strip 32 is provided both in front of, as well as, behind the electrostatic air boundary layer swirler 10.

**[0114]** Fig. 4 shows a schematic representation of a further arrangement comparable to that in Fig. 1, whereby, however, a suction device 36 is connected downstream from the electrostatic air boundary layer swirler 10.

**[0115]** The electrostatic air boundary layer swirler 10 is advantageously again arranged at a distance "a" (see e.g., Fig. 1) of a maximum of approximately 1000 mm from the gap 24, whereby this distance preferably lies again in a range of approximately 100 mm to approximately 500 mm.

**[0116]** The excess swirled air is purposefully removed by the suction device 36, through which the desired air pressure in front of the closing gap 24 can be regulated. In this connection, a suctioning that can be regulated zone by zone is also conceivable in order to render it possible to remove locally different volumes.

**[0117]** Parts that correspond to one another are assigned the same reference number in the embodiments already described in accordance with Figs. 1 through 4 as well as in the case of the embodiments described in the following in accordance with Figs. 5 through 9.

**[0118]** Fig. 5 shows a shows a schematic representation of an electrostatic air boundary layer swirler 10 used in the press section, which is arranged in the area of a web transfer location where the fibrous material web 12 is accepted by a felt 38. In this connection, the electrostatic air boundary layer swirler 10 is assigned to a revolving belt 26 accepting the fibrous material web 12, and the belt 26 is guided around a roll 30 in the area of the transfer location. In the area of this roll 30, a gap

24 arises again, in front of which the electrostatic air boundary layer swirler 10 is arranged. In this connection, the electrostatic air boundary layer swirler 10 assigned to the revolving belt 26 is arranged in machine direction L in front of the roll 30 and correspondingly in front of the gap 24.

**[0119]** As was previously the case, here too, the electrostatic air boundary layer swirler 10 can again be provided optionally in combination with a deflecting strip 32 that is connected downstream and/or upstream and/or in combination with a suction device 36 that is arranged downstream.

**[0120]** The transfer location shown in Fig. 5 can be provided after a double-felted press, for example.

**[0121]** Fig. 6 shows a schematic representation of another electrostatic air boundary layer swirler 10 used in the press section, which in this case, however, is arranged in the area of a web transfer location where the fibrous material web 12 is accepted by a smooth roll 40. In this connection, the electrostatic air boundary layer swirler 10 is again assigned to a revolving belt 26, for example, a felt belt, which accepts the fibrous material web 12.

**[0122]** The electrostatic air boundary layer swirler 10 is again arranged in front of a gap 24, which is formed in this case between the smooth roll 40 and a suction guide roll 42, over which the felt 26 is guided.

**[0123]** Fig. 7 shows a schematic representation of two electrostatic air boundary layer swirlers 10 used in the press section, one of which is arranged in the area of a transfer roll 28 and the other is arranged in the area of a single-felted press 44.

**[0124]** The transfer roll 28 is arranged between a smooth roll 40 of another, preceding likewise single-felted press 46 and a deflection roll 48 around which the felt 26 being fed into the press 44 is guided. The transfer roll 48 is used simultaneously as the counterelectrode 16 of the first electrostatic air boundary layer

swirler 10. Its charging electrode 14 is arranged in front of the gap 24 formed between the smooth roll 40 and the transfer roll 28.

**[0125]** As can be seen in Fig. 7, the second electrostatic air boundary layer swirler 10 is assigned to the felt 26 and is provided in machine direction L in front of the gap 24 of the single-felted press 44. In this connection, the charging electrode 14 and the counterelectrode 16 of this second air boundary layer swirler 10 are provided on different sides of the felt.

**[0126]** As can be seen in Fig. 7, the first press 46 can be a long gap press and the second press 44 can be a roll press, for example.

**[0127]** Just as with all other embodiments, in the case at hand, the respective electrostatic air boundary layer swirler 10 can also be provided optionally in combination with a deflecting strip that is connected downstream and/or upstream and/or in combination with a suction device.

**[0128]** Fig. 8 shows a schematic representation of an electrostatic air boundary layer swirler 10 used in combination with a moistener or a dampener 50 (for example, nozzle moistener or steam moistener) in a machine to manufacture a fibrous material web 12. The moistener 50 can be provided for transverse moisture profiling in the drying section, on a dryer screen suction roll, for example. In this case, the counterelectrode 16 can be formed by the relevant dryer screen suction roll.

**[0129]** In the embodiment at hand, the fibrous material web 12 runs supported on the roll 16 that preferably simultaneously forms the counterelectrode 16. The laminar air boundary layer 20 is carried along with the fibrous material web 12 until it is swirled by the plasma beam or stream 18 between the charging electrode 14 and the roll forming the counterelectrode 16. The turbulent air flow 22 caused by this process can be penetrated more easily by the spray streams 52 of the moistener 50.

**[0130]** To further increase efficiency, the turbulent air flow 22 can optionally be kept away from the spray beams or streams 52 of the moistener 50 by a deflecting strip 32 so that the spray 52 can act in a low-current environment. Alternatively or additionally, a suction device 36 can reduce the turbulent flow 22.

**[0131]** In the case of the moistener 50, this can be a nozzle moistener in particular. However, a corresponding combination is also conceivable with a steam moistener, for example, or with a steam blower box, for example.

**[0132]** Fig. 9 shows a schematic representation of another exemplary embodiment of an arrangement with an electrostatic air boundary layer swirler 10 used in combination with a moistener 50. In this case, several of the different possible options should be identified again in particular.

**[0133]** Thus, in the case of the moistener 50, this can again be a nozzle moistener with several nozzles 54, for example. As already mentioned, however, in principle a steam moistener, for example, or a steam blower box in combination with a respective electrostatic air boundary layer swirler 10, can also basically be provided.

**[0134]** The relevant electrostatic air boundary layer swirler 10 again includes a charging electrode 14 and a counterelectrode 16 that can be formed, for example, by a grounded roll in particular.

**[0135]** The charging electrode 14 of the electrostatic air boundary layer swirler 10 can be integrated into the moistener 50 or also be provided as a separate unit.

**[0136]** The plasma beam or stream 18 generated between the charging electrode 14 and the counterelectrode 16 breaks up the laminar air boundary layer 20 thereby generating a turbulent swirled air flow 22.

**[0137]** A suction device 36, for example, can be provided behind the electrostatic air boundary layer swirler 10 or its charging electrode 14 in order to suction off at

least a portion of the turbulent air flow 22 generated by the electrostatic air boundary layer swirler 10.

**[0138]** Alternatively or additionally, a suction 56 can be provided in the moistener 50 in order to suction off excess air and excess mist from a spray chamber 58 that can be formed, for example, between a deflecting strip 32 between the charging electrode 14 and the nozzles 54, a strip 60 arranged at the rear end on the outlet side of the moistener 50 as well as lateral strips that are not discernible in Fig. 9.

**[0139]** It is noted that the foregoing examples have been provided merely for the purpose of explanation and are in no way to be construed as limiting of the present invention. While the present invention has been described with reference to an exemplary embodiment, it is understood that the words which have been used herein are words of description and illustration, rather than words of limitation. Changes may be made, within the purview of the appended claims, as presently stated and as amended, without departing from the scope and spirit of the present invention in its aspects. Although the present invention has been described herein with reference to particular means, materials and embodiments, the present invention is not intended to be limited to the particulars disclosed herein; rather, the present invention extends to all functionally equivalent structures, methods and uses, such as are within the scope of the appended claims.

List of Reference Characters

| | |
|---|---|
| 10 | Electrostatic air boundary layer swirler |
| 12 | Fibrous material web |
| 14 | Charging electrode |
| 16 | Counterelectrode |
| 18 | Plasma current, plasma stream |
| 20 | Laminar air boundary layer |
| 22 | turbulent, swirled air flow |
| 24 | Gap |
| 26 | Revolving belt |
| 28 | Rotating roll |
| 30 | Roll |
| 32 | Deflecting strip |
| 34 | Remaining gap |
| 36 | Suction device |
| 38 | Felt |
| 40 | Smooth roll |
| 42 | Suction guide roll |
| 44 | Single-felted press |
| 46 | Single-felted press |
| 48 | Deflection roll |
| 50 | Moistener |
| 52 | Spray streams |
| 54 | Nozzle |
| 56 | Suction |
| 58 | Spray chamber |

60 Strip

a Distance

b Distance

L Machine direction